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AN ANALYSIS OF THE GROWTH OF THE PALM OIL INDUSTRY IN SUMATRA, INDONESIA: AS DETECTED BY SATELLITE IMAGERY, 2000-2018

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ABSTRACT

Palm oil trees are rapidly spreading across the landscape in Sumatra, Indonesia. The province of Bengkulu is a prime example of this, and it is hard to go anywhere and not see palm oil trees. Finding an accurate way to monitor plantation growth would be of great benefit as scientists and others attempt to monitor how Indonesia's palm oil boom is affecting climate change. Several studies have indicated that the surge of palm oil production is causing great environmental and social harm to Indonesia as well as the rest of the world. This research details a methodology for utilizing satellite imagery to accurately differentiate palm trees from other forms of vegetation on a plantation scale. The research applied as unsupervised classification process found in ArcMap to a series of LANDSAT's 4-5, 7, and 8 satellite imagery for palm tree detection. The results of this study show that the rate of palm oil expansion was still growing up to 2018. However, the study was inconclusive as to whether or not the Indonesian government is in compliance with the New York Declaration on Forests, signed in 2014, where they pledged to not deforest any new land.

INTRODUCTION

My research objective is to measure, quantifiably, the growth of palm oil plantations in Bengkulu, Sumatra, Indonesia, from 2000-2018. This time period is significant because in the year 2000, the price of palm oil went up, and it became an important economic driver for the Indonesian economy (Cason, 2000). Since 2000, the government of Indonesia and exporting companies have been engaged in clearly unsustainable practices in deforesting land for these plantations. However, in 2014, the government and several of the largest palm oil exporters signed the New York Declaration of Forests which says that they will cut the amount of

deforestation on any new land in half by 2020, and fully by 2030 ("Goal 1…" n.d.). Whether or not compliance to the accord could be determined using satellite imagery was one of my prime research questions. In conjunction with this, I was also interested in how deforestation effects the local population, because in the past, people have not been treated or paid well. The local population also has a clear dependence on the native forests for many purposes including, but not limited to, food, biofuel, and shelter.

My initial hypothesis was that new land has been deforested because, according to Forest Trends, it is estimate that, between 2000-2012, eighty percent of deforesting was illegal, and palm oil accounted for three quarters of this illegal activity (Schiffman, 2014). Finally, my primary research questions are:

1. How have palm oil plantations grown since the increase in the price of palm oil, 2000;
2. What are the social and environmental impacts of the palm oil industry on the local population; and
3. Is the government of Indonesia complying to the New York Declaration on Forests, and not using any new land for palm oil plantations?

LITERATURE REVIEW

About ninety percent of the world's palm oil is being produced in Malaysia and Indonesia (Rainforest Rescue, n.d.). There are three types of palm oil plantations in Indonesia: those owned by the government, those owned by local people (privately owned), and those owned by corporations. These plantations are not a new concept and have been criticized for their devastating environmental and social effects. However, after spending time in Indonesia and

talking to many local people, it is clear that many locals do not have the same attitude towards the issue.

Palm oil became renowned all over the world because with only one hectare of land it is able to produce up to twelve times more oil than any other oilseed plant (Libraswulan, 2014). But before being able to plant these palm oil fields, whoever owns the area must deforest large amounts of land. This practice is not sustainable because once you plant these palm oil trees, they are only fruitful for about thirty years before leaving the area barren, and you must then obtain, and subsequently deforest, more land. One way that people deforest these areas are with the slash and burn technique. Slash and burn is a cheap and effective tool to clear land, one basically just lights the entire field on fire, and once the fire is out, it is covered in a nutrient rich ash (EcoLogic Development Fund, n.d.). However, many of these fields in Indonesia are peatlands. Peatlands are mixtures of decomposing materials in a water rich environment (International Peatland Society, n.d.). Peat is mostly what falls from trees (leaves, wood pieces, etc.), which do not fully decompose in water logged conditions (anaerobic) and can be from one foot to sixty-five feet deep, the height of a six-story building (Union of Concerned Scientists, 2013). Slash and burn practices will often ignite the bogs. It is hard to put a peat fire out and they can smolder under the surface for months or years and can be incredibly dangerous (Vander, 2017). This fire and smoke pose a risk to the local people. Peatlands are carbon sinks holding eighteen to twenty-six times the amount of carbon than in the forest on top of it, which means that slash and burn not only releases the carbon from the standing forest into the atmosphere, but also massive amounts of carbon and methane from the peatland below (Union of Concerned Scientists, 2013). Additionally, the burning and destruction of the land leads to increased soil erosion and degradation as the land becomes unprotected against heavy tropical rainfall.

Soil erosion occurs when large amounts of forest are deforested or "when clearing is not undertaken properly in the establishment of plantations" (WWF, 2014). One clear example of improper clearing was in 2001 in the Riau Province of Sumatra, Indonesia, the fallen trees were collected in piles up and down hillsides rather than in contour-type lines to prevent runoff, and the running water eroded most of the fertile topsoil down the hill (WWF, 2014). After the existing vegetation is taken out, there is a higher chance of flash flooding to occur and large silt deposits often end up in rivers and other bodies of water (WWF International, n.d.). This becomes a very expensive problem that Yhoga Klelana, from the University of Bengkulu (UNIB), touched on when we were in Bengkulu. Once the topsoil is gone, farmers have to pay for fertilizer and soil to be trucked to the site and laboriously applied to their fields.

Another reality of deforestation is loss of biodiversity, with regard to both plants and animals. Deforestation, in the case of plantations, takes away all native plant life and replaces it with a homogeneous environment. This strips thousands of native animal species of a viable habitat. According to the Union of Concerned Scientists, "only about 15 percent of native animal species can survive the transition from primary forest to plantation" (Union of Concerned Scientists, 2013). A few of the most notable victims of the replacement of the native land cover are: orangutans, tigers, rhinoceros, elephants, and sun bears (BSBCC, 2010) (Union of Concerned Scientists, 2013). Once these animals are gone, they are not coming back, which creates large gaps in the natural food web, and eventually leads to the collapse of entire ecosystems. This collapse will eventually make its way up the chain to humans, and our food supply. Most animals die of starvation or prolonged exposure to harsh elements without any kind of protection, but some wander into human populated areas. Much of the local population consider, orangutans in particular, "pests" and will beat them to death (Rainforest Rescue, n.d.).

In 2006, 1,500 orangutans were clubbed to death by plantation workers, according to the Centre for Orangutan Protection (Rainforest Rescue, n.d.). These human-animal conflicts are, unfortunately, becoming more and more common as more and more of the orangutans' traditional areas are converted to plantation, monoculture agriculture (WWF International, n.d.).

When something this large scale is being discussed, the implications on climate change are inescapable. Because of Indonesia's carbon rich soil, these forests store more carbon per hectare than the Brazilian Amazon (Union of Concerned Scientists, 2013). Just one of these hectares, when burned, releases 6,000 tons of carbon into the atmosphere (Rainforest Rescue, n.d.). Tropical deforestation accounts for eighteen percent of all global greenhouse gas emissions, and Indonesia ranks third among all nations in the emitting of greenhouse gases compared to other nations (Rainforest Rescue, n.d.) (WWF International, n.d.). These carbon sinks need to be protected and preserved if humans have any chance of stopping and reversing the effects of climate change.

In 2007, the Rainforest Action Network (RAN) began targeting Cargill, the largest exporter of palm oil to the United States, in an effort to pressure the company to "stop buying oil grown on newly cut forests and peatlands" (Schiffman, 2015). However, this was unsuccessful, so RAN decided to go after the people to whom Cargill supplies the oil to – the "snack food twenty" (Schiffman, 2015). The snack food twenty are the twenty largest food corporations, corporations like Campbell Soup Company; Dunkin' Brands Group, Inc.; General Mills, Inc.; H.J. Heinz Company; Kellogg Company; Kraft Food Group, Inc.; Krispy Kreme Doughnuts Corp.; Mars Inc.; Nestlé S.A.; PepsiCo, Inc.; The Hershey Company; and Unilever (Rainforest Action Network, n.d.). This strategy proved to be successful, and companies started demanding to be supplied with palm oil what was not from newly deforested land (Schiffman, 2015). In

September 2014, Cargill, along with over half of the snack food twenty, endorsed the *New York Declaration on Forests* (Schiffman, 2015).

It has been said that, in recent years, "palm oil [is] the single largest driver of tropical deforestation" (Schiffman, 2015). In an effort to combat this on an international scale, one hundred and thirty governments signed the *New York Declaration on Forests* at the UN Climate Summit, in 2014 (Schiffman, 2015). One of those governments is Indonesia. Although the government may seem to be onboard, Forest Trends estimate that, between 2000-2012, eighty percent of deforesting, in Indonesia, was illegal (Schiffman, 2015). Palm oil accounting for three quarters of this illegal activity (Schiffman, 2015). Government support goes along way, but is clearly not enough. The Indonesian government needs to start cracking down on these illegal deforesters before it is too late, and entire species' homes are destroyed, millions or CO2 emissions are released, and local people are dead.

Aside from the obvious environmental hazards that are associated with deforestation, the local people are in danger as well. Haze from these deforestation fires spread across Indonesia, Singapore, and Malaysia. A study was reported in the journal Environmental Research Letters by Harvard and Columbia researchers that found one hundred thousand people died in 2015 from smoky, fine particle haze (Associated Press, 2016). However, Indonesia, Singapore, and Malaysia have all, separately, rejected these findings. Indonesia's disaster mitigation agency said the research "could be baseless or they have the wrong information," and only reported twenty-four deaths included people who died fighting the fires (Associated Press, 2016). Singapore reported that the death rate remained unchanged from the previous year to then, and their Ministry of Health said the study was "not reflective of the actual situation" (Associated Press, 2016). Finally, Malaysia's Health Minister, Subramaniam Sathasivam, said "people have

died but to what extent the haze contributed to it, it's hard to say" (Associated Press, 2016). One study that noted these fires was done in the province of Borneo, Indonesia. The researchers wanted to study the correlation of forest loss and industrial plantations in that region (Gaveau et al., 2018). They noted that over forty percent of forest loss in Indonesian was to forest fires (findings not yet published). The researchers even found the late 2015 satellite imagery to be unusable, citing smoke from fires (Gavaeu et al., 2018). Finally, the fires in Borneo corresponded with the 2016 peak of deforestation in the province (Gavaeu et al., 2018).

On the social issue of work treatment in Sumatra, very few people have positive accounts. The few positive accounts are mainly associated with successful instances of tied smallholder schemes, and farmers who "mobilized" and negotiated better terms with the palm oil industry (Li, 2015). Documented negative impacts in Sumatra have been documented to include: lack of appropriate health facilities, lack of access to healthy food, and corporations paying wages below the legal limit (Libraswulan, 2014). Palm oil workers have had to survive on cassava leaves and instant noodles, while not being paid enough to send their children to higher education institutions, so the cycle of poverty continues (Libraswulan, 2014). Palm oil has been in Indonesia for over a century, and it seems the conditions have not improved at all over that time. The government of Indonesia cannot even step in to help alleviate some of these injustices. A corporation in Sumatra, Badan Kerja Sama Perusahaan Perkebunan Sumatra, was paying their laborers below what the law requires, while making more money since the price of palm oil was up, and the government was completely unable to punish the organization for this illegal activity (Libraswulan, 2014).

In conjunction with the World Wildlife Federation (WWF), many major palm oil producers created the Roundtable on Sustainable Palm Oil (RSPO) (Rainforest Rescue, n.d.).

The RSPO has attempted to set a standard for establishing "sustainable palm oil," and brands who meet these standards will have the RSPO logo on their product. However, they are not against deforestation in general, only "high conservation value" forests (Rainforest Rescue, n.d.). What exactly a high conservation value forest is, was not explicitly stated. Green Peace International has spoken out against RSPO and said that this is nothing "more than green washing."

Similar studies have been conducted in the past, but none for the specific province of Bengkulu, Indonesia, or with the method used in my research. One study published in Volume Eight of PLoS ONE investigated land use changes and greenhouse gas emissions from forest conversion by palm oil plantations (Ramdani and Hano, 2013). Their study area was the Riau Province, Sumatra, Indonesia, and used Landsat 5 TM and Landsat 7 ETM+ imagery (Ramdani and Hano, 2013). Ultimately, they used a hybrid integration method decision tree analysis in ENVI (Ramdani and Hano, 2013). Another study published in the Journal of Remote Sensing, focuses on palm oil detection in Thailand (Srestasathiern and Rakwatin, 2013). The study's methods focus on using QuickBird imagery of the Phang-nga province of Thailand, and the researchers had hoped to detect individual palm oil trees. They hand-marked the boundary of the plantations and by using a vegetation index, developed a system where the computer marked and counted each individual tree.

METHODOLOGY

This remote sensing project utilized LANDSAT imagery from LANDSAT's 4-5, 7, and 8 recorded during the months March-May. This time of the year was selected as it typically has the least amount of cloud obstruction. It was important to use the same timeframe from year to

year, so the cycle of plantation growth is the same. The land classification was run in the ArcGIS software ArcMap and was the only software used throughout this project.

After obtaining the imagery from the United States Geological Survey (USGS), ArcMap was used to clip and mosaic specific bands from the LANDSAT image for the Bengkulu province. An unsupervised classification was originally tried at the province scale, but was unsuccessful. It appears that the classes were not specific enough, for example it was classifying all the vegetation together rather than just the palm oil. The area was clipped again around the boundary of two palm oil plantations and one rubber plantation. This boundary was hand drawn by ground truthing with Google Earth Pro. Google Earth Pro is a great tool and resource for a project like this where historical imagery is needed. Next, an unsupervised classification was conducted to measure the growth for two palm oil plantations (PT Bio Nusantara Teknologi and PT Sandabi Indah Lestari) and the oldest, largest rubber plantation for reference (PT Pamor Ganda).

The classification was deemed overall successful after further ground truthing with Google Earth Pro. A binary was established of what is palm oil and what is not for the two palm oil plantations, and a ternary for the rubber plantation of what is rubber, palm, and other. This ground truthing was done by finding multiple points of reference (significant bends in a river, coast line marker, etc.) and checking several points before confirming a class identity.

RESULTS

All Figures and Tables Referenced in this section can be found after Acknowledgements on page 14. The growth is measured in pixels, on LANDSAT satellite image each pixel covers an area thirty meters by thirty meters in size. Several years were eliminated because of clouds or

other imagery impediments, and also because of time constraints. In the end, images for the years 2000, 2008, 2015, and 2018 were the years selected and analyzed. Rubber was ultimately the hardest thing to differentiate from the natural forest cover as their reflectance signals are quite similar, and this method of identification was considered to be less accurate for rubber. As can be seen with 2015 in Figure 1. While the classified image appears to show multiple categories the reality on the ground was that virtually the entire area is covered by rubber, as shown in Figure 2 from Google Earth Pro. This could be attributed to a problem with the quality of the imagery playing a role on how well the ArcMap software can analyze and subsequently classify each pixel. In addition to ArcMap having trouble with imagery, ground truthing was also a challenge when imagery looked like it does in Figure 3 and 4, from 2000, again of PT Pamor Ganda. This imagery was next to impossible to ground truth because of the quality of the data for that timeframe. Because of how similar the natural forest is to the rubber plant, being able to accurate ground truth was ultimately unfeasible. 2000's imagery was not sharp enough, and 2018 was unusable because of clouds, and the classifications for 2008 and 2015 were not accurate enough to delineate. The use of imagery to accurately classify palm oil tree proved far more successful. For PT Bio Nusantara Teknologi, the growth from 2000 to 2018 can be seen in Table 2 and is undeniable. The price of palm oil began to stabilize or go down during the past few years, which could account for the slight dip from in the extent of palm oil on the images for 2015 to 2018, but it could also be from clouds or other imagery interferences (Gaveau et al., 2018). For PT Sandabi Indah Lestari, the growth seen in Table 3, is even more evident than in the PT Bio Nusantara Teknologi table.

CONCLUSION/DISCUSSION

Overall, the study was a success. Palm oil can be detected through an unsupervised classification, and the results show what was originally hypothesized – palm oil plantations are growing at a high rate. However, what was also discovered along the way was just how many small personal plantations there are. People are planting palm oil plants literally in their own backyards to make money. The addition of rubber into the study was helpful because it shows a point of reference, however due to rubber's close spectral signature to that of the native forests, the unsupervised classification was unable to accurately distinguish rubber from native forest. The study did show that small land owners were planting their own palm oil trees, the classification process of the satellite images clearly detected these small palm oil plots for the years 2008, 2015 as did the Google Earth Pro imagery for 2018. Whether or not the government of Indonesia is complying with the New York Declaration on Forests is still undetermined, based on this study. The results from the small areas analyzed in this study may or may not reflect the state of forests for the rest of the province, or country as a whole. However, palm is clearly expanding over new land, as seen in Tables 2 and 3. The methodology utilized in this study was shown to be reliable and could provide a basis for classifying a much larger area (i.e. the entire province) which could be utilized to determine whether or not the government is in compliance with the New York Declaration on Forests.

ACKNOWLEDGEMENTS

I would first like to thank my Honors Mentor, Dr. Patton, for helping me take on such an ambitious remote sensing project and learning about palm oil along the way. I would also like to thank Dr. Hall Brown for answering countless questions when there was seemingly no end to the

software and my user errors. Finally, I have to acknowledge the help and support from Bengkulu, Indonesia, from Dr. Aceng Ruyani for sending resources in helping me choose a province, and my friends on the ground for help when the only resources I could find were in Bahasa Indonesia – Yhoga Klelana, Muhammad Fendra, and Juwita Wartomo. Without the help from all listed parties, this project would not have been possible.

FIGURES AND TABLES

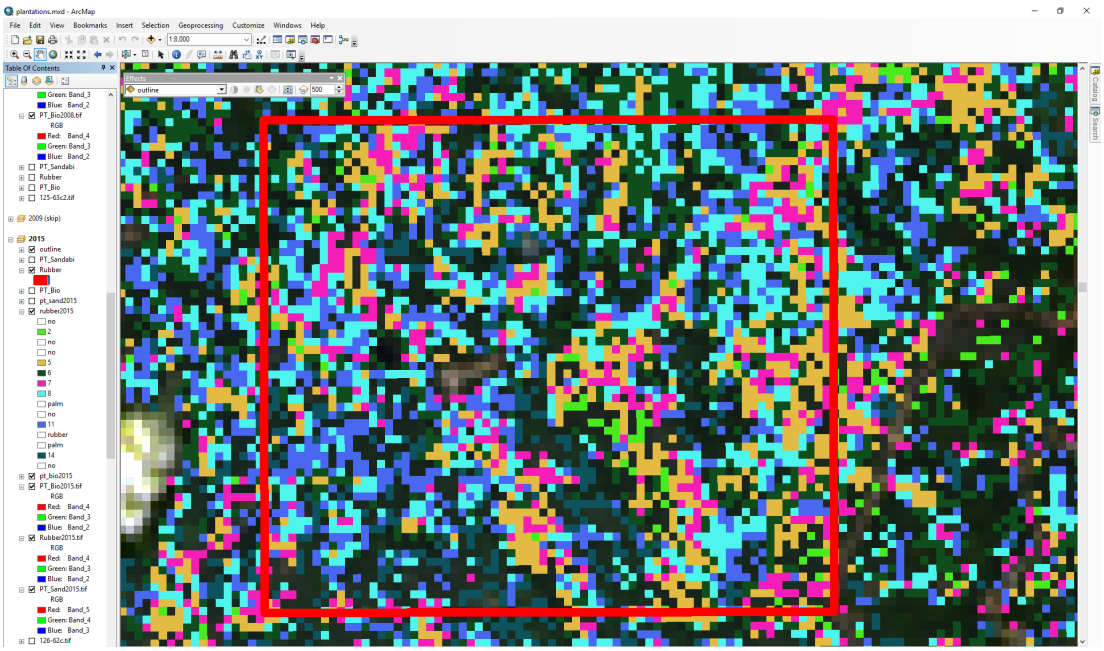

Figure 1: ArcMap Viewer, 2015

Figure 2: Google Earth Pro Imagery of PT Pamor Ganda, 2015

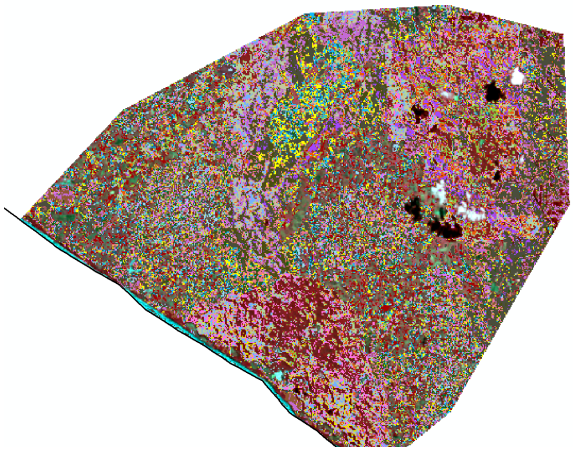

Figure 3: PT Pamor Ganda View in ArcMap

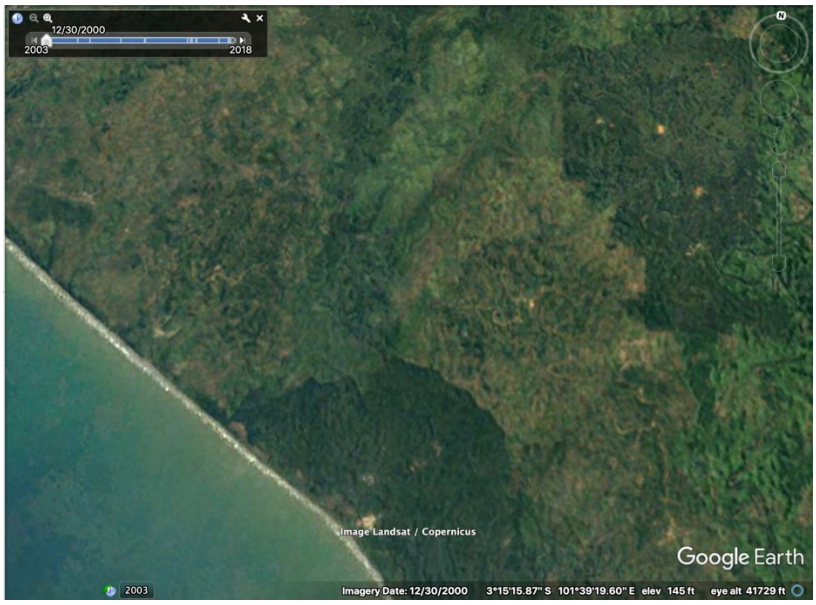

Figure 4: Google Earth Pro 2000 view of PT Pamor Ganda

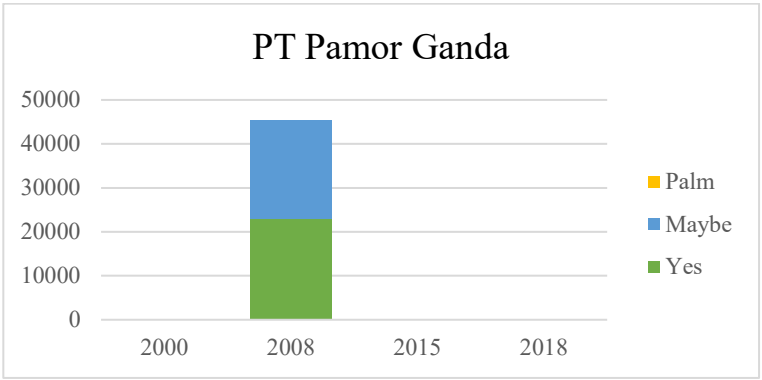

Table 1: Rubber Plantation Growth

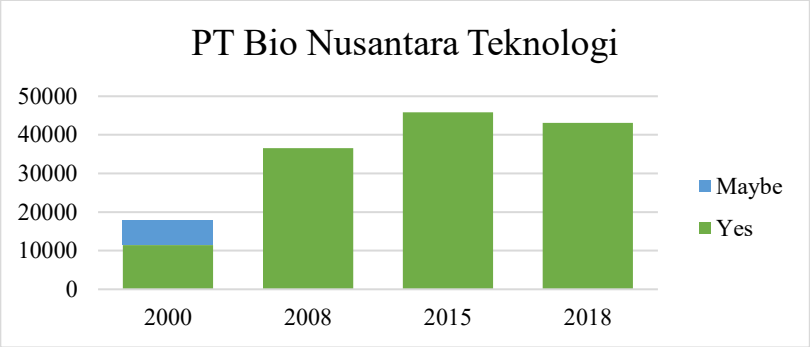

Table 2: PT Bio Plantation Growth

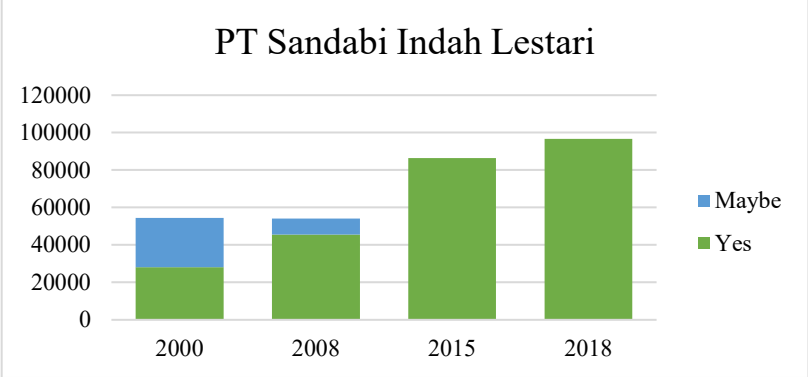

Table 3: PT Sandabi Plantation Growth

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